SEE FOLLOWING NOTE

PLEASE NOTE THAT PAGE REFERENCES MAY APPEAR IRREGULAR; HOWEVER, TEXT IS COMPLETE AS PRINTED.

VOIR NOTE CI-APRÉS

VEUILLEZ NOTER QUE LA PAGINATION PEUT SEMBLER IRRÉGULIÈRE; CEPENDANT, LE TEXTE IMPRIMÉ EST INTÉGRAL..

micromedia
a division of IHS Canada

20 Victoria Street
Toronto, Ontario M5C 2N8
Tel.: (416) 362-5211
Toll Free: 1-800-387-2689
Fax: (416) 362-6161
Email: info@micromedia.on.ca

Saskatchewan

A D F

Agriculture Development Fund

FINAL REPORT

EARTHEN MANURE STORAGE DESIGN FOR EFFECTIVE SOLID SEPARATION

19980121

Funded by
The Agriculture Development Fund
March 2000

Prepared by: PAMI

100-05343/

Project No. RH7098
Date: March 2000
Tested at Humboldt

ADF# 98000121

Final Report

Earthen Manure Storage Design for Effective Solid Separation

Alan R. Boyden, A.Sc.T.
Project Technologist

Darrell Lischynski, P.Eng.
Manager, Energy and Processing

Philip J. Leduc, P.Eng.
Manager, Research and Development

James D. Wassermann, P.Eng.
Station Manager

Acknowledgements

PAMI wishes to acknowledge the funding support provided by the Agriculture Development Fund of Saskatchewan Agriculture and Food.

Table of Contents

Page

1. Summary 1
2. Technical Report 2
   - 2.1 Introduction 2
   - 2.2 Objectives 2
   - 2.3 Recommendations 3
   - 2.4 General Description 3
   - 2.5 Scope of Test 4
   - 2.3 Results and Discussion 5

4. Equipment 15
5. Project Developed Materials 16
6. Project Photos 17
7. Acknowledgements 18

9. References 20

1. Summary

Research was done to examine the behaviour of solids in liquid manure. This information is intended to be used to ensure that two-cell Earthen Manure Storages (EMS) are designed to be cost effective and optimize the amount of solids that stay in the primary cell of the storage. Lab tests were done to determine settling times. The distribution of solids in several EMS's was also determined. It was determined that the solids settle out of suspension a few hours after agitation, and that after 25 days, compaction of the solids is complete. The solids do not necessarily settle in all manure types. The orientation of the EMS inlet does not affect the solids settling, and other mechanisms are working to distribute the solids within an EMS.

2. Technical Report

2.1 Introduction

Almost all of the liquid manure in Saskatchewan is stored in Earthen Manure Storages (EMS). These are excavations that are designed to hold more than a year's supply of manure and have a compacted liner that is meant to minimize manure movement into the soil and water beneath the EMS. The manure that is introduced into the EMS is typically raw, in that it contains both liquid and solid portions. Over time the solid portion settles out of suspension and the manure must be agitated during pump out to remove as much solids as possible. To minimize this agitation, many EMS's are built with a primary settling cell and a secondary overflow cell. It is intended that the solids will all settle out in the primary cell and only the liquids will overflow through a weir into the secondary cell. Therefore, if this system is working as intended, the secondary cell would not have to be agitated during pump out, which would be a significant saving in time and management.

There are many different two-cell EMS designs in use today, which incorporate different loading methods, cell sizes and other factors. Because not much information is available about how solids settle and how they move in an EMS, many of the designs are evolutions of previous designs and many of the changes are determined by trial and error. This project was done to learn more about the solids in raw manure, how they settle and how they move within an EMS. It is hoped that this information will help EMS designers to optimize the two-cell concept to minimize construction and operating costs.

2.2 Objectives

The objectives of this project were to:

1) Observe the settling characteristics of several raw manure samples.

2) Investigate behaviour of solids in several earthen manure storages.

3) Provide guidelines than can be used to aid future designs of two-cell earthen manure storages.

2.3 Recommendations

It is recommended that the following factors be considered when designing an Earthen Manure Storage:

1. The primary cell should be about one-third of the total EMS volume. This value is not absolute for all situations and it is dependent on the barn type.
2. The orientation and location of the manure inlet does not affect solids settling. Other factors, such as plugging and freezing should be considered when deciding upon inlet configuration and location.
3. A square primary cell will make agitation easier and more effective.

2.4 General Description

2.4.1 Settling Trials

Manure settling trials were done in the lab by placing raw manure into plastic columns and observing the settling characteristics. These columns were made of PVC, had a nominal diameter of 12 in., and were 10.5 ft high. Because of a related project, there also was a column of soil beneath the liquid manure to examine the manure movement through the soil. Six sampling ports were installed at various heights in the columns. Plastic windows were also installed along the height of the columns to visually observe the solids level in the column. **(Figure 1)**

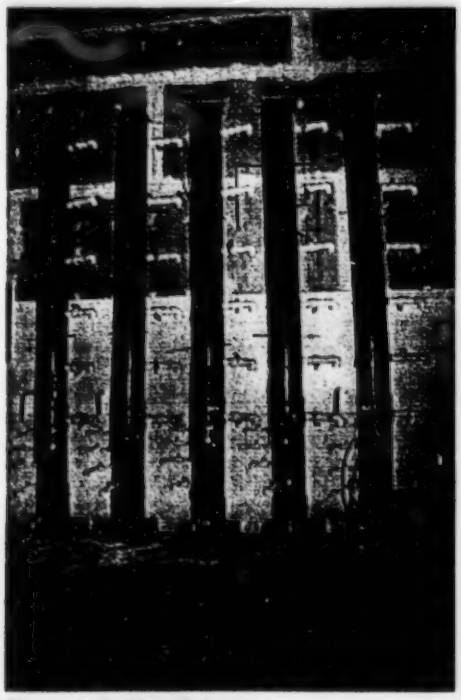

Figure 1. Settling Columns.

2.4.2 EMS Solids Profiles

The solids level in several EMS's was determined in the second part of this project. Two boats were connected together and nine locations next to the boats were designated as sampling locations. The boats were positioned at various locations in the EMS, with the location determined by measuring the distance to known points on the shore, or by using a land surveying total station. At each location an aluminum rod with a tape measure attached to it was used to determine the solids depth. The operator slowly lowered the rod down through the manure and noted where the top of the solids level occurred, as well as the bottom of the EMS.

2.5 Scope of Test

2.5.1 Settling Trials

These tests were done in cooperation with the University of Saskatchewan, Agricultural and Bioresource Engineering Department (ABE). Different types of soil were placed in the bottom section of each column as ABE was researching the movement of manure through soil. Raw manure from five different barns was collected by placing a submersible pump in the EMS near the EMS inlet. A manure sample was drawn out while manure was flowing from the barn into the EMS. A description of the types of manure samples collected is given in **Table 1**.

Table 1. Manure Sample Descriptions.

Column No.	Barn Type	Feed
1	Finisher	Prepared on-site
2	Farrowing/Breeding	Prepared on-site
3	Farrow to Finish	Prepared on-site
4	Nursery	Prepared on-site
5	Farrow to Finish	commercially prepared

When all samples were collected, each was thoroughly mixed, a sample taken for analysis, and the manure placed in each column. The level of sediment was noted for several months. At the end of the test, manure samples were collected from the sampling valves and analyzed for solids content by a manure analysis laboratory.

2.5.2 EMS Solids Profiles

The initial activity in this portion of the project was to obtain input on the current state of the art in EMS design from several people in the industry. These included barn operators, barn developers and people who have designed EMS's. Information from this exercise was used to determine further project direction.

The other activity in this portion of the project was to determine profiles of the solids level in several EMS's. The previously mentioned boat and aluminum rod test method was used to determine the level of solids and total manure depth at various locations. In three of the EMS's examined, the profile was determined near the EMS inlet both before and after the manure was transferred from the barn to the EMS.

Some other solids measurements were also taken in various locations throughout the EMS. In two EMS's, solids depths were determined at various locations.

2.6 Results and Discussion

2.6.1 Settling Trials

As soon as the agitated manure was placed in the columns, the solids began to separate out of suspension. **(Figure 2)**

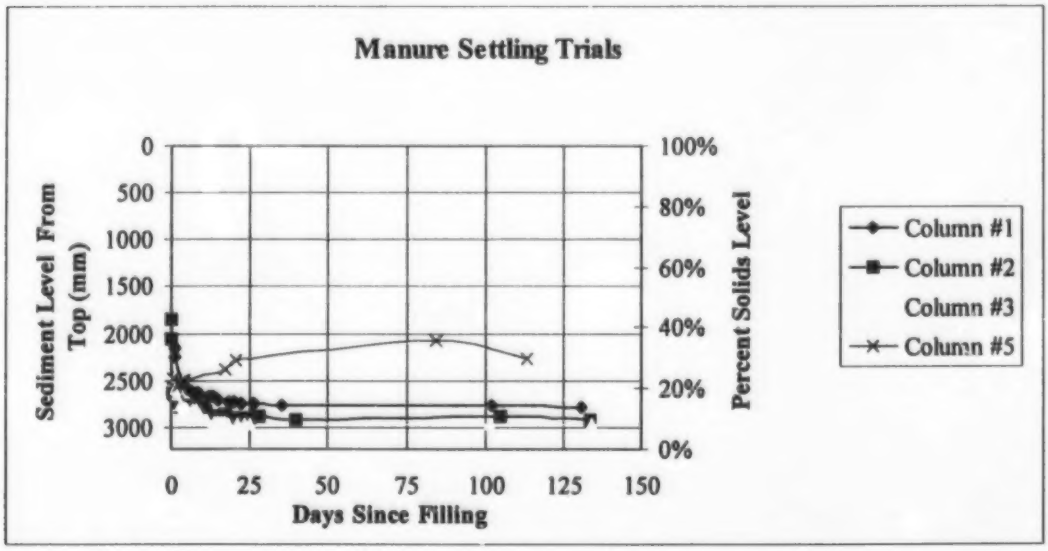

Figure 2. Column Settling Results.

In one case, a definite line marking the top of the solids was visible 1.5 hours after the manure was placed in the columns. As time went on, the solids compacted and after 25 days, most columns had settled out nearly as much as they would eventually. Throughout the test, there was no visible distinction between solids and liquids in column #4. This is understandable, as this manure came from a nursery barn and there would be very little solids from these small animals. Another note is that the manure in column #5 did not settle out like the manure in columns #1 through #3. It was observed that at the liquid/solid interface there was more bubbling and biological action

in this column than in others. This caused the solids to be continuously disturbed and they could therefore not compact as well as in other columns.

Besides measuring the level of solids in the columns, the dry matter content in the initial agitated manure sample was determined. Results of both of these tests are given in Table 2.

Table 2. Solids Content Comparison.

Column #1	Raw Manure % Dry Matter (a)	% Solids Level In Column (b)	Ratio b/a
1	2.3	14	6.1
2	0.7	10	14.1
3	1.4	8	5.7
4	1.4	0	N/A
5	3.8	30	7.9

The dry matter percentage of the raw manure is consistently much lower than the level of solids measured in the columns. In fact, if columns #1, #3, and #5 are averaged, the ratio of the two is about 6.6. The dry matter contains enough water while in the EMS that it occupies considerably more volume than when it is completely dried.

It is accepted knowledge that the dry matter content of liquid hog manure is typically 4-6% and can be as high as 8-10%. If 5% was used as a representative amount, and the ratio of solids level to dry matter percentage of 6.6 are multiplied, the resulting value of 33% would represent the size of primary cell of an EMS, relative to the entire EMS volume. This, in fact, matches the proportions of many EMS designs and confirms that an EMS built with these proportions is probably near to the optimal volumetric ratio. Of course, the actual amount of solids in the manure from a given barn will change depending on the feed characteristics, animal type, and management practices, such as amount of wash water. An EMS can be designed with a larger primary cell. This would reduce the chance of solids carrying over into the secondary cell, but would increase the amount of manure that must be agitated. The opposite is true of a smaller primary cell.

It should be noted that the solids in the bottom of some columns had up to 14% dry matter, but in another related project, solids sampled from a full-size EMS were above 50% dry matter. This indicates that the dry matter content of manure solids at the bottom of an EMS can vary greatly. The consequence of this variation is that solids with a higher dry matter content would be more difficult to agitate or pump.

2.6.2 Survey Results

The results from discussions with several barn operators and designers were varied. Below is a summary of the comments received.

The location of the manure inlet into the EMS didn't seem to be a large concern for anyone. The inlet location was typically dictated by the barn's location relative to the EMS. Some entered the EMS along one side and some were in a corner of the EMS. No one really noted any problems with having the inlet in any specific location.

The orientation of the inlets was also varied. Some storages were top loaded, in that the inlet was always above the liquid level. These inlets have the advantage that they always have the opportunity to drain between pumping and therefore are not likely to plug with solids. However, they do discharge the manure through the air and therefore the odour level can be higher than from submerged inlets. If used with an EMS which is straw covered, the cover will likely be destroyed near the inlet, as the manure flow will disturb the cover and cause it to sink.

Many inlets were placed part way up the wall of the EMS. Some were located from 1/3 to 2/3 of the wall height up from the EMS floor. The goal was to locate the inlet high enough up that it is above the solids level when the EMS is full, but below the liquid surface level during winter. Because the inlet is submerged during most of the year, the odour is reduced and if a straw cover is in place, it will not be disturbed as much.

Some inlets were located at the bottom of the EMS. The advantage of these inlets is that they are almost always submerged in liquid and therefore not likely to freeze or cause any disturbance to the liquid surface. However, because they are likely to be below the level of solids in the EMS, they are more likely to plug with solids and disturb the settled solids around the inlet when the manure is transferred from the barn to the EMS. Because of the potential for plugging, these inlets are most often used with a system that uses a pump as opposed to a gravity fed system.

The flow of manure from the barn to the EMS can either be by gravity or pumped. Gravity systems are simple and require little maintenance, but are only possible if a slope of 1 to 1 ½% can be maintained between the barn and the EMS. Because gravity is the only force moving the manure through the pipes, liquid velocities can be low, and these pipes can be prone to plugging if they are not managed properly or if slope is incorrect.

If a pump is used, the system is less likely to plug, as more pressure can be created to clear small blockages. When a pump is used, the inlet to the EMS can be placed anywhere, as it will be less likely to plug if it is below the solids level. Because friction

loss is not a large concern, smaller pipe can be used, which reduced installation cost. However, operation of the pump causes a higher operating cost than a gravity system.

Some systems incorporate both gravity flow and a pump. For instance, some systems use a pump to get the manure from the barn to a manhole on the bank of the EMS and the manure flows by gravity from here. This system has the advantage that a pump is used to move the manure most of the way to the EMS, but the inlet into the manhole is designed in such a way that there is a vacuum break between the barn and the EMS.

Both gravity and pumped systems work well when designed well and are operated as designed. Operators reported some plugging problems, but most were due to operation problems such as leaking pit plugs and having too many pits being emptied at once.

Regarding EMS size, it was generally accepted that the primary cell should be square, to make agitation easier and more effective. Because of the practical area of influence of a manure agitator, the maximum length of one side of the primary cell was taken to be 200 ft. The relative sizes of primary and secondary cells varied from the primary being 15 to 35% of the total volume.

In general, there are many different EMS designs being used today. The actual design for any given barn is typically based on the designer's previous experiences and the operator's preference. No one design appears to work significantly better than the other in all cases. Many of the design decisions are based on engineering principles, but some others, such as cell size and inlet location, are only based on past experience, with no science to quantify the values chosen.

2.6.3 EMS Solids Profiles

For this part of the project, the solids profiles were measured in three EMS's. The first EMS did not have much solids in any location of the primary cell. There were only a few inches of solids near the inlet, and almost none in other locations within the primary cell. Therefore, nothing could be learned about the effect of the inlet, because there was almost no solids to disturb during filling. Although there were not many solids at the bottom of the cell, the primary cell had a crust on top and the secondary cell didn't. It was also noted that there was quite a lot of biological activity in the primary cell, as a bubble would often emerge on the liquid surface. This activity could have been stirring the solids enough to prevent long-term solid settling.

The second EMS sampled had a good amount of solids near the inlet. This barn was a feeder barn and the inlet was part way up the bank of the EMS. The manure was moved from the barn to the EMS by pump every day. The solids profile near the inlet was

determined before and after the manure was pumped from the barn to the EMS. The following three figures show the changes in solids profiles before and after filling.

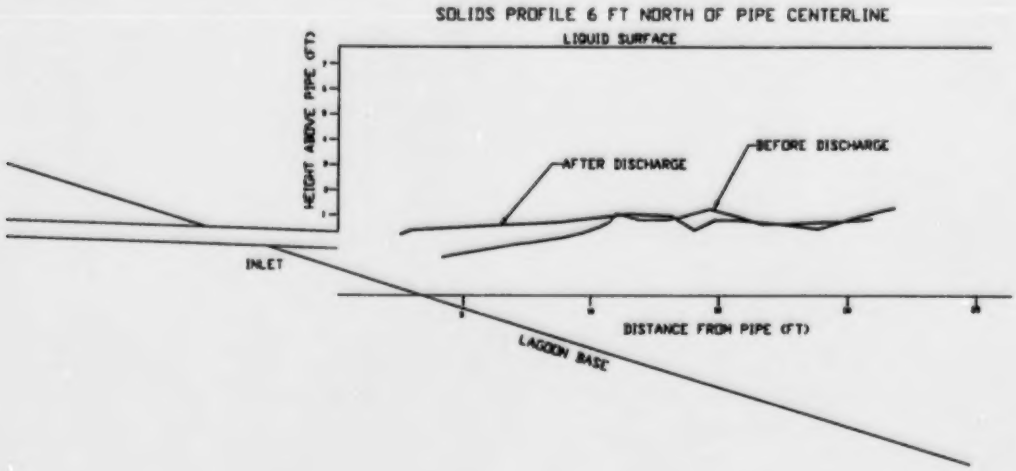

Figure 3. EMS #2 Solids Profile 6 ft. North of Inlet.

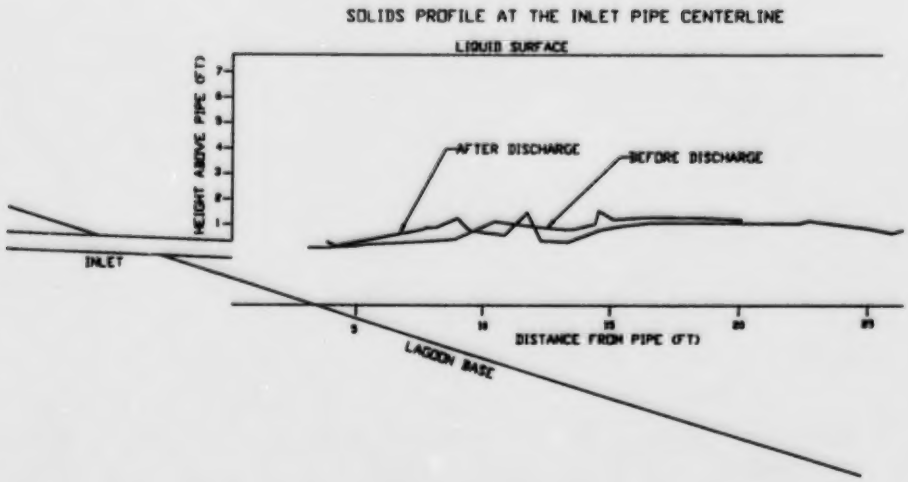

Figure 4. EMS #2 Solids Profile at Inlet.

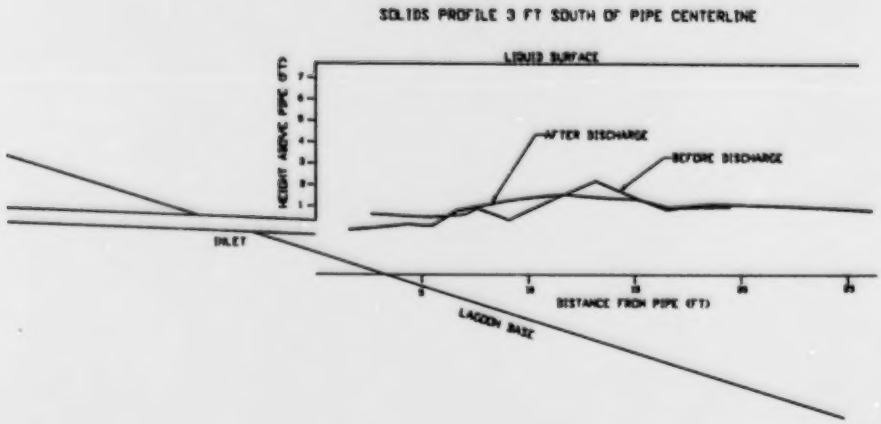

Figure 5. EMS #2 Solids Profile 3 ft. South of Inlet.

Based on the above results, it does not appear that the profile of the solids near the inlet was affected by the flow of manure during filling. If this was the case in all EMSs, then the location and orientation of the inlet would not affect the amount of settling in the primary cell. This would make designing the EMS less restrictive to obtain maximum long-term liquid/solid separation. To test this theory, the same tests were repeated in a different EMS.

The third EMS sampled had a similar amount of solids compared to the second EMS. The barn was a farrow-to-finish unit and the inlet was near the top of the bank of the EMS. The manure was pumped into the EMS every 3 - 4 days. The solids profile near the inlet was determined before and after the manure was pumped from the barn to the EMS. The following three figures show the changes in solids profiles before and after filling.

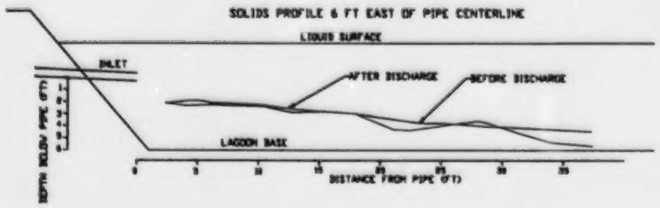

Figure 6. EMS #3 Solids Profile 6 ft. East of Inlet.

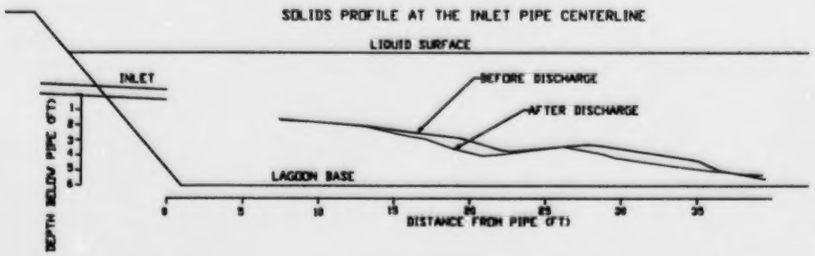

Figure 7. EMS #3 Solids Profile at Inlet.

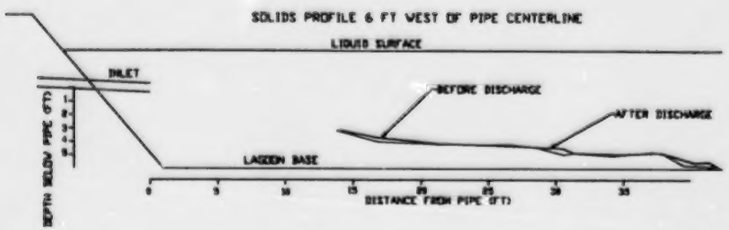

Figure 8. EMS #3 Solids Profile 6 ft. West of Inlet.

The above results confirm the conclusion from the second EMS in that the solids near the inlet are not significantly disturbed by the manure entering the EMS.

As a matter of interest, the solids level in other parts of this EMS were determined. It was found that the level of solids in most of the EMS was similar to that near the inlet. It is highly unlikely that the solids travelled to the far ends of the storage directly from the inlet, so they must have gotten there by some other transport method. It is also known from the column lab tests that much of the solids settle out of suspension within the first few hours after filling. If this was the only mechanism at work, then one would expect that most of the solids would be near the inlet, which was not the case. Therefore, there must be some other mechanism that moves the solids from near the inlet to the far ends of the EMS over time. One possibility is that biological action causes bubbles or other low density pockets that rise from within the solids and appear at the surface. This action is evident in many EMS's. If this was so, it could stir the solids enough to move them laterally enough to flatten any "hills" and therefore redistribute the solids throughout the EMS. Another possibility is that convection currents due to surface heating and cooling and wind action may be contributing. If this is the case, covering a lagoon may lessen this effect. In any case, the solids move in the EMS and the inlet configuration and location has little effect on liquid/solid separation. If some other mechanisms determine the degree of settling, then the only design factor that could be changed to ensure effective settling would be the size of the primary cell relative to the entire EMS volume. A primary cell that was large enough would ensure that the solids

level does not rise above the level of the weir or transfer pipe between the two cells and therefore would ensure that a minimum of solids entered the secondary cell.

2.6.4 Design Suggestions

One of the objectives of this project was to provide guidelines for EMS design to ensure effective liquid/solid separation. Below are suggestions for two-cell EMS design, based on the findings of this project.

It appears that with manure from most barns, the primary cell should be 1/3 of the total EMS volume. If the EMS is for a nursery barn with very little solids produced, this size could be reduced, and the proportion would have to be increased for a feeder barn. Other factors, such as amount of wash water used, will also affect the primary cell size.

It is not known if the type of feed will affect the amount of solids in the manure, or why crusting occurs in some EMSs and not others. Making the primary cell square appears to be a good suggestion to increase the ease and effectiveness of agitation. Basic geometry would suggest a round design would agitate the most efficiently but construction would be difficult.

Based on the findings of this project, it appears that the location and orientation of the manure inlet has little effect on the liquid/solid separation that occurs in an EMS. It would probably be desirable to not locate the inlet too close to the outlet, but other than this, it appears that any type of inlet will work fine. The primary concerns when deciding on an inlet should be reducing plugging, and keeping the pipe from freezing. The manure velocity coming from the inlet pipe does not appear to affect settling, so choosing a gravity or pumped system should also not affect settling.

Some of the above suggestions imply a validation of present practices. This does provide confirmation that two-cell EMS's are being designed to optimize liquid/solid separation while also being cost effective.

4. Equipment

No equipment was purchased for this project.

5. Project Developed Materials

No materials have been developed from this project to date. Information from this report will be incorporated in a future PAMI Research Update.

6. Project Photos

Photos for this project are contained within the body of the report.

7. Acknowledgements

To date, the results from this project have not been publicized. In all future press releases, reports or other information dissemination, support from the Department will be acknowledged.

9. References

Brumm, M.C., Sources of Manure: Swine, *In Animal waste utilization: effective use of manure as a soil resource* / edited by J.L. Hatfield, B.A. Stewart, ISBN 1-57504-069-9, Ann Arbor Press, Chelsea, Michingan,1998.